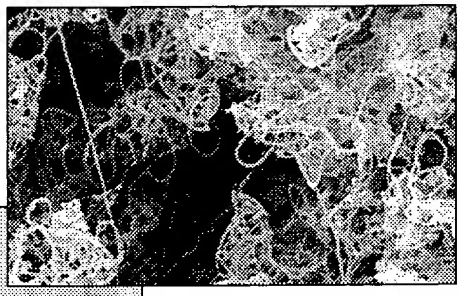
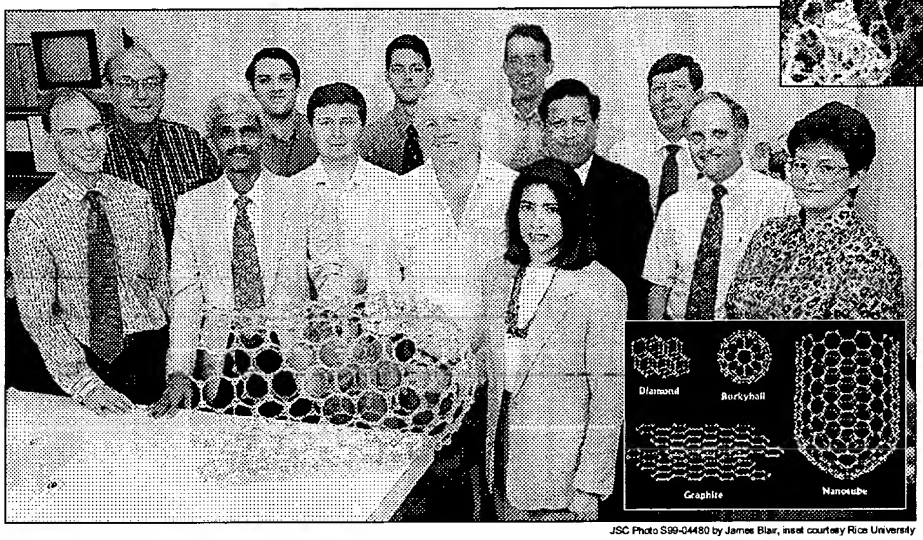
Carbon nanotubes: *JSC's role in the advancement of nanotechnology*

By Beatrice Santos

- A millimeter diameter cable capable of lifting the weight of four average cars
- Nanorobots that travel through the bloodstream removing plaque and bacteria
- Stronger composite structures at a fraction of the weight
- A balance capable of weighing single cells in the 10^{-15} gram range



Unpurified nanotube rope image taken by scanning electron microscopist Lou Hulse.



JSC Photo S99-04480 by James Blair, inset courtesy Rice University

The Nanotube team members are from left, front: Brad Files, Sivaram Arepalli, Pavel Nikolaev, Benny Ewing, Beatrice Santos, Rick Barrera, Carl Scott, and Olga Gorelik; back: Joe Victor, William Holmes, Brian Mayeaux, Leonard Yowell, Bill Proft. Team members include employees of NASA, GB Tech, Lockheed Martin, Hernandez Engineering and Rice University.

'Nanotube composites will have a strength-to-weight ratio of 10-100 times that of today's structural materials.'
–Brad Files

The scenarios listed above are at least theoretically possible because of the relatively new field of nanotechnology. Nanotechnology could enable significant technological advancements for future space flight. Advancements such as ultra-lightweight composites, advanced energy storage devices and nanoscale computers to govern nanorobots might all be possible using carbon nanotubes. An ongoing project led by Brad Files of the Manufacturing, Materials and Process Technology Division (MMPTD) at JSC is focusing on carbon nanotubes for such applications.

What Are Carbon Nanotubes?

Fullerenes were discovered in 1985 at Rice University by Richard Smalley, Robert Curl and Harold Kroto, who were awarded the Nobel Prize in chemistry in 1996. The most basic fullerene is comprised of 60 carbon atoms arranged in a geodesic pattern, named the buckyball (inset above) in honor of Buckminster Fuller. A carbon nanotube is an elongated buckyball about a nanometer in diameter (about 1/50,000th the diameter of a human hair). NASA shares the growing interest in single-walled carbon nanotubes because of their extraordinary mechanical, electrical and optical properties. In the axial direction, they exhibit electrical conductivity as high as copper, thermal conductivity as high as diamond and strength approximately 100 times greater than steel at 1/6th the weight. According to Richard Smalley, "It should be the strongest fiber that you can make of anything – ever. In the strength/ weight ratio sweepstakes, it should be the ultimate fiber."

JSC Photo S99-04478 by James Blair

Brad Files, left, and Rick Barrera inject a nanotube epoxy composite.

Current Activities at JSC

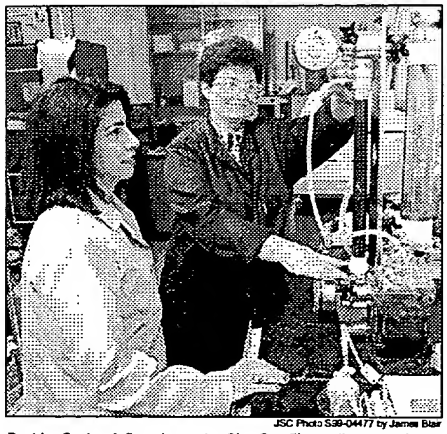
The laser nanotube facility, headed by Sivaram Arepalli (GB Tech), uses two pulsed lasers impinging on a composite graphite target to produce and study the growth mechanisms of nanotubes. It is one of the few facilities in the world focusing on understanding nanotube formation. This understanding could lead to bulk production methods, thereby reducing cost and increasing worldwide availability. Another promising method for bulk production being investigated is the arc method. Built under the direction of Carl Scott (Structures and Mechanics Division), it uses an electric arc to vaporize an anode to produce nanotubes.

The major goal of the MMPTD project is development of composites for structural applications. After production, the nanotubes are processed in the purification facility, which was built by Beatrice Santos (MMPTD). They are then ready for incorporation into epoxy composites for testing. Future work will include evaluation of various composite matrix systems. A complementary study is being conducted by Enrique Barrera (Rice University) using thermoplastic composites for electrically conductive applications. Dr. Barrera is a senior fellow of the National Research Council, currently on sabbatical at JSC.

In addition, JSC supports nanotechnology development through the Small Business Innovative Research Program. There are several applications being investigated including the use of nanotubes for low power flat panel displays and ultracapacitors for energy storage.

JSC's Role in Nanotechnology

In 1997 Lubert Leger, former deputy chief, MMPTD, spearheaded the construction of a nanotube production facility at JSC, modeled after the Rice University facility. In 1998, NASA Administrator Dan Goldin and Malcolm Gillis, president of Rice University, signed a cooperative agreement pledging a collaborative effort between the two institutions to develop carbon nanotechnology. For more information on JSC's ongoing efforts and the latest nanotube developments for space applications, see the monthly newsletter at http://www.jsc.nasa.gov/ea/em/nano.

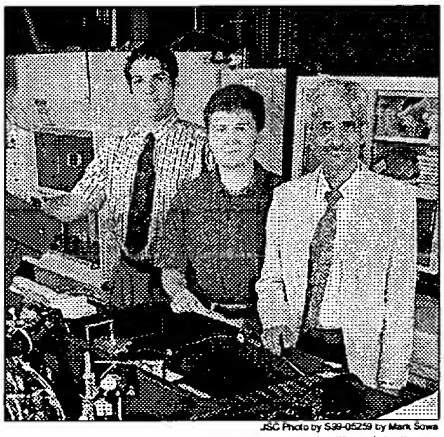


JSC Photo S99-04477 by James Blair

Beatrice Santos, left, and operator Olga Gorelik run the nanotube purification facility.

Toward the Future

Carbon nanotechnology could make human interplanetary space exploration a reality through the creation of advanced technologies which were science fiction only ten years ago. The prohibitive weight penalty of current interplanetary spacecraft could virtually disappear with the application of nanotechnology. According to Doug Cooke, manager of JSC's Exploration Office, "It takes forty pounds of spacecraft and systems in low earth orbit to get each pound of mass to the Mars surface and back. Nanotechnology in structures is important for all space travel. [It] has the potential for us to make the next big step since Apollo." ■



JSC Photo by S99-05259 by Mark Sowa

William Holmes, Pavel Nikolaev, and Sivaram Arepalli work in the laser nanotube production lab.